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Biomass Readiness: The Chicken or The Egg

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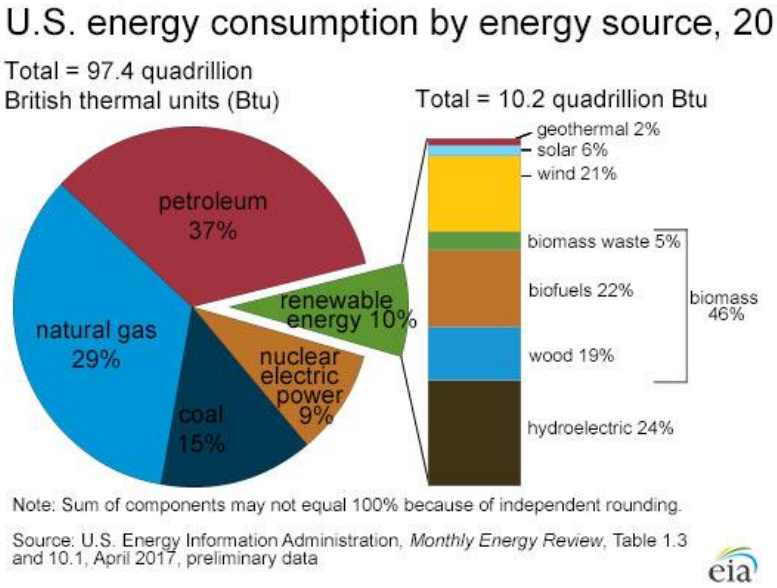
Renewable Energy Transition

- Driving Factors
  - Fossil fuel supplies
  - Environmental impacts
  - Changes in technology
  - Cost/Price

Picture Source: ERM-Siam Co., Ltd

Renewable Energy Economy

- Electricity, Heating, Cooling
  - Hydropower
  - Wind
  - Solar
  - Geothermal
  - Biomass



- Transportation Fuels
  - Biomass
    - Herbaceous and woody plant material

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What can these crops be used for?

Sugar Crops



Sugar Beets, Sugar Cane, Sweet Sorghum

Starch Crops



Corn, Sweetpotatoes, Wheat

Lignocellulosic Materials



Corn Stover, Wood Fiber, Grasses

Oil Seeds



Soybeans, Canola, Camelina

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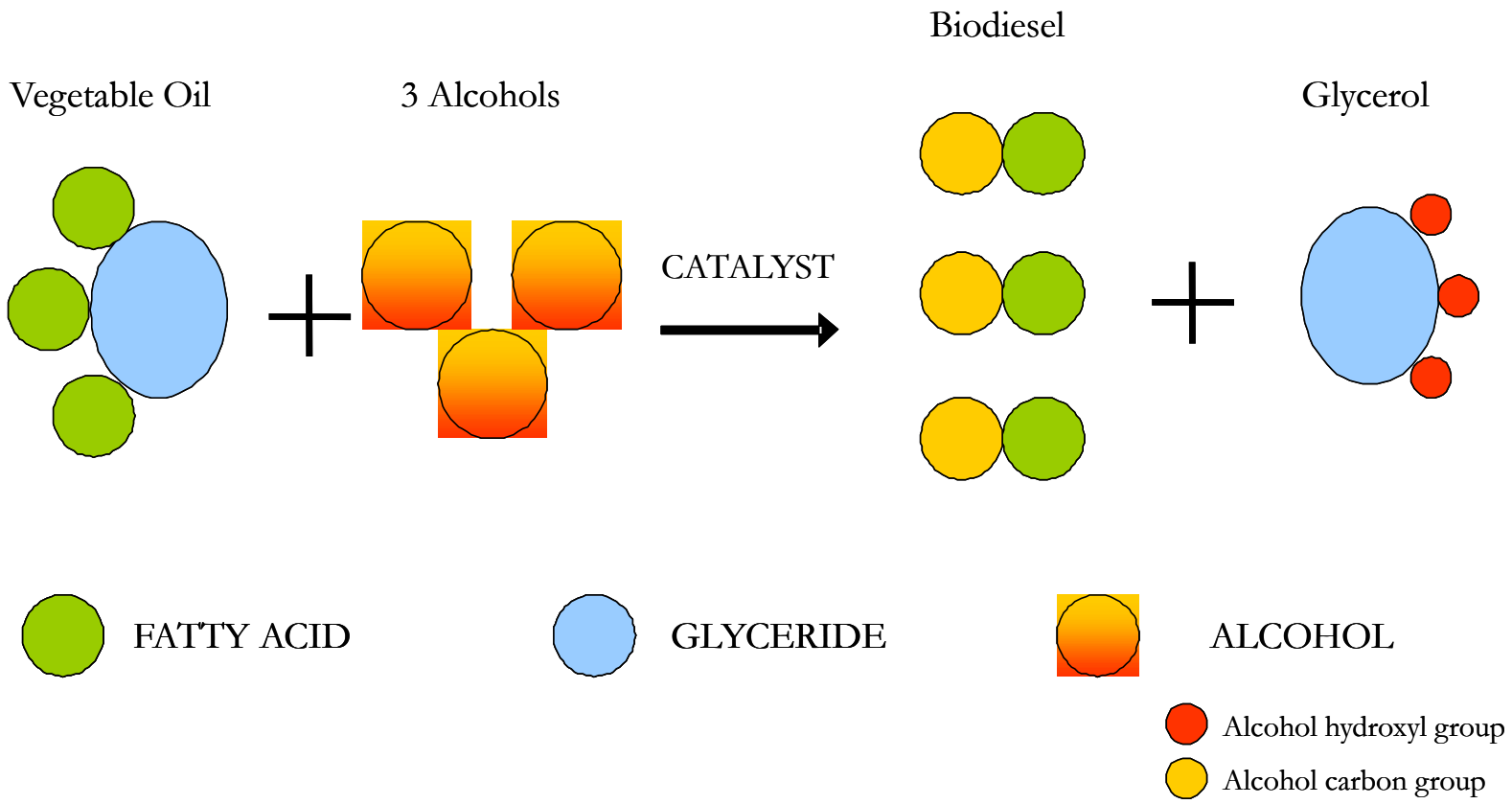
Tranesterification for Biodiesel



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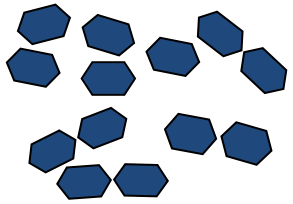
Sugar Crop Conversion

Strip and Press Stalks

Concentrated Juice Production



Simple sugars—sucrose, glucose and fructose

Animal Feed

Bagasse

Fermentation & Distillation

Lignocellulosic Conversion

Liquid Fuels

Renewable Bio-based Products

e.g. pharmaceuticals, building block chemicals, polymers, biofuels, heat

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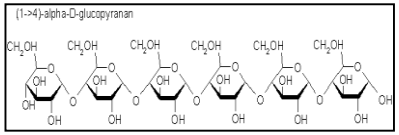
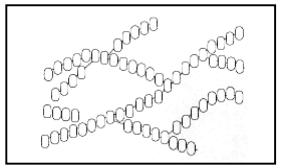
Starch Conversion Process

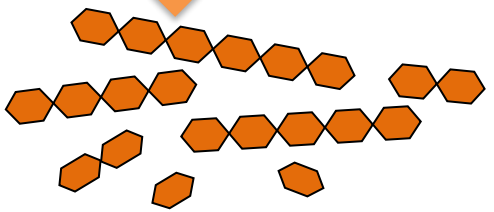


amylose



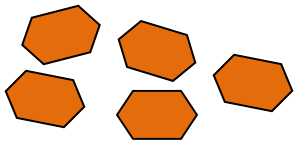
amylopectin

Liquefaction
α-amylase, 85°C

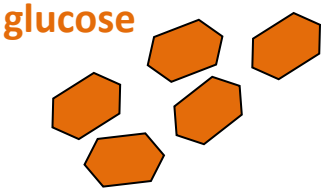


maltodextrins

Saccharification
glucoamylase, 55-65°C
pullulanase, pectinase



Simple sugars—
glucose



Fermentation

Pharmaceuticals

Liquid Fuels

Building Block Chemicals

Renewable Bio-based Products

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Lignocellulose Conversion Process

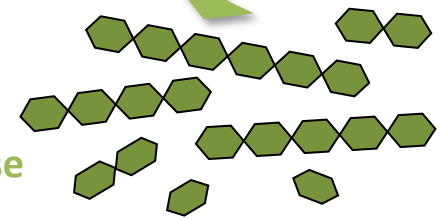
Lignin

Cellulose

Hemicellulose

Pretreatment

chemicals, high pressure & temperature



Reduced lignin content

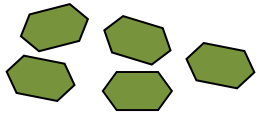
Dextrins-C6, C5

Hydrolysis

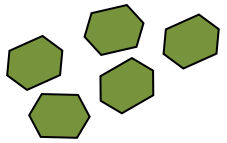
cellulases

β–glucosidase 50°C

xylanases



Simple sugars—glucose, galactose, xylose, mannose, arabinose



Fermentation

The Sugar Platform

Pharmaceuticals

Liquid Fuels

Building Block Chemicals

Renewable Bio-based Products

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Lignocellulose Conversion Process

Lignin

Cellulose

Hemicellulose

Torrefaction

Gasification

Pyrolysis

Synthesis gas—CO, CO_2, H_2, CH_4
Hydrocarbons
Pyrolytic oils
Char

Electricity

Fischer Tropsch
Processing
Chemical or Microbial
Catalysts

Biochemicals

Soil amendments

Liquid hydrocarbons and fuels
e.g. diesel, olefins, gasoline, ethanol, methanol

Renewable Bio-based Products

The Thermochemical Platform

Reduction of biomass under high temperatures and limited or no oxygen

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Sugar Platform

Lignocellulosic Crops
Lignin, Cellulose, Hemicellulose

Feed Stock Logistics
Processing and Handling

Pretreatment

Reduced Lignin Content

Starch Crops
Amylose, Amylopectin

Feed Stock Logistics
Processing and Handling

Enzymatic Hydrolysis

Sugars

Sugar Crops
Sucrose, Fructose, Glucose

Feed Stock Logistics
Processing and Handling

Microbial Fermentation

Liquid Fuels

Value Added Chemicals

Thermochemical Platform

Lignocellulosic Crops
Lignin, Cellulose, Hemicellulose

Feed Stock Logistics
Processing and Handling

Torrefaction → *Char (e.g. soil amendments)*

Gasification → *Gas Cleaning* → *Gas Conditioning* → *Fisher Tropsch/ Bio Catalysts* → *Liquid Hydrocarbons and Fuel*

$CO_1CO_2H_2$

Pyrolysis → *Bio Oils* → *Fuel Refining*

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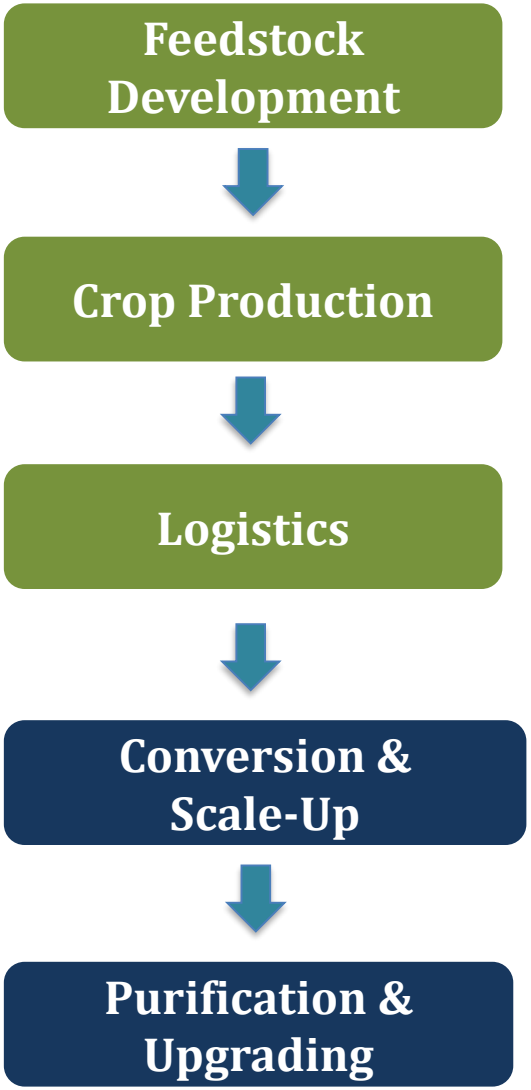
Supply Chain Development & Integration



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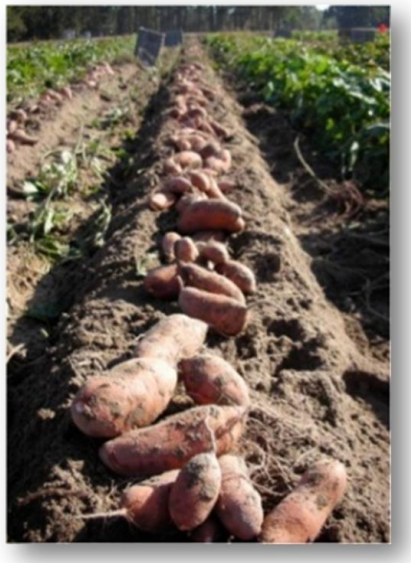
Feedstock Development & Crop Production

- ✓Conversion characteristics
- ✓Yield
- ✓Water and nutrients
- ✓Pests and disease
- ✓Minimize inputs
- ✓Develop know-how
- ✓Diversification
  - ✓Regionally appropriate



Feedstock Logistics

- ✓Harvest and collection
- ✓Preprocessing
- ✓Storage and shelf-life
- ✓Transportation

Conversion & Purification

- Improve efficiency
  - lower cost
  - higher product yields
  - multiple feedstocks
  - reduce unit operations
- Innovation and refinement
- Complement biomanufacturing

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Herbaceous Energy Crops
Potential Energy Content

Crop	Dry Yields (ton/ac)	Energy Content (million Btu/ac)	Energy Content (gal gasoline equiv./ac)
Biomass Sorghum Annual	7.5 – 14.8	120 – 236	996 – 1959
Miscanthus Perennial	7 – 13	112 – 208	930 – 1726
Switchgrass Perennial	4.7 – 8.4	74.4 – 134	618 – 1109

- Augment petroleum based fuels and chemicals
- Net energy ratios are different
  - composition
  - processing requirements
- Land availability and intermittent supply

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What is the best crop for this field?

- Supply & Demand
  - Farmer driven
  - Biorefinery driven
- Transitional Markets
  - Intermediate
  - Value-added
- Incentives
  - Starting directions
  - Price points
- Biomass Readiness
  - Integrated R&D

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